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Interactive comment on "Small-scale gravity waves in ER-2 MMS/MTP wind and temperature measurements during CRYSTAL-FACE" *by* L. Wang et al.

L. Wang et al.

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Reply to Anonymous Referee # 1

1. Major Comments

1. We agree that λ_h is more physically meaningful than λ'_h. Nevertheless, λ'_h is an important intermediate quantity in dealing with the aircraft data for the following two reasons. Firstly, λ'_h can be directly estimated from the MMS data (by using the S-transform or other wavelet analysis, see P. 11382-11383). λ_h, on the other

hand, cannot be estimated directly. It has to be derived either from λ_h' and the angle between the GW horizontal propagation direction and the flight direction (P. 11384, L. 4-7), or from vertical fluxes of zonal and meridional momentums (P. 11338, L. 13-14). Secondly, the existence of a GW event is detected by examining whether coherent wave perturbations show up in both temperature and at least one component of horizontal winds at the same flight distance and at the same λ_h' (P. 11383, L. 15-18). Thus, it is worth of showing the statistics of λ_h' in the paper (left panel of Fig. 5, P. 11405).

The statistics of λ_h is actually implied in Fig. 10 (P. 11410) of the original draft. *"As expected, λ_h is shorter than λ_h', and most of the events have λ_h between 5 and 15 km (in comparison, λ_h' is mostly 10-20 km)"*. To address the reviewer's concern on the lack of description of λ_h, we will add the above quoted text at line 10 on page 11386.

In addition, in the revised paper, we will define the apparent horizontal wavelength λ_h' when it first appears in the paper (P. 11383, L. 1) instead of deferring it to P. 11384, L. 4-7 in the original manuscript.

2. The co-existence of longer and shorter horizontal wavelength waves can be seen more clearly from the 1-D data (in particular in MMS u, MMS & MTP T in Fig. 2, P. 11402). It is evident that the shorter scale signal is embedded in the longer signal for both u and T, and this is consistent with what is revealed from the S-transform analysis (Fig. 5, P. 11404). It is harder to see the shorter horizontal wavelength signal in the MTP temperature contour plot (Fig. 3, P. 11403) partly because that its amplitude was smaller than that of the longer wave so that it is overshadowed in the contour plot.

   We neglected to mention in the paper that we actually performed statistical testing on the S-transform analysis. Specifically, for all the wave events we identified, we required that the amplitudes of T and at least one wind component be above the 95% confidence level (in addition to the other requirements stated in the paper,

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i.e., P. 11383, L. 16-18). The statistical testing is based on Stockwell, 1999: S-transform analysis of gravity wave activity from a small scale network of airglow imagers, Ph.D. thesis, The University of Western Ontario, 1999. We will add this and the reference in the revised paper.

3. We share the concern of the reviewer regarding the possible presence of a sampling bias in the aircraft data. We will add the following notes on such a bias at the end of section 5 (P. 11392, L. 28) and section 6 (P. 11394, L. 25), respectively, in the revised paper.

   "Finally, we note that the ER-2 aircraft flight paths were chosen to avo id areas directly above deep rain events where the most vigorous GW motions might be present. Such a sampling bias in the aircraft data likely causes an under estimation of the actual GW amplitudes in the statistics reported in this study."

   "Finally, note that the statistics reported in this study likely underestimate the real GW amplitudes in the region due to the sampling bias in the ER-2 aircraft."

2. Minor Comments

(a) In the original draft, the definition of λ_z' is provided on P. 11384, L. 4-7. We will move the definition to P. 11383 when we first mention the "apparent horizontal wavelength" in the revised paper.

(b) The choice of 5 km is not due to the wavelet transform. We study only those GW events which had λ_z' no shorter than 5 km because otherwise there would be too few MTP data points to derive the vertical wavelengths of the events reliably. Also, very short GWs are more severely affected by processes such as thermal dissipation, reflection, etc., than longer ones, so we cannot use the simple ray-tracing algorithm (P. 11388-11389) to trace

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them to their sources. The value of 5 km was (arbitrarily) chosen to reflect the above concerns.

(c) θ is the angle between the flight direction and the GW horizontal direction ϕ (P. 11384, L. 5-6), i.e., $\theta \equiv \phi - \gamma$ where γ is the flight direction (measured contour-clockwise from the East). Since $\cos\theta$ can be either positive or negative depending on which quadrant θ is located in and λ_h is always positive by definition, we will replace "$\lambda_h = \lambda'_h \cos\theta$" (P. 11384, L. 5) with "$\lambda_h = \lambda'_h |\cos\theta|$" in the revised paper.

(d) We will add the following GW dispersion relation on P. 11386, as suggested by the reviewer.

$$m^2 = \frac{{\lambda_h}^2}{{\lambda_z}^2} \frac{\left(N^2 - \hat{\omega}^2\right)}{\left(\hat{\omega}^2 - f^2\right)} - \frac{1}{4{H_\rho}^2} \tag{1}$$

where H_ρ is the density scale height calculated from the MTP data.

(e) We will change the relevant sentence (P. 11388, L. 14-16) as follows: *"We compared the propagation directions derived using the flux method with those from the Stokes parameter method, and found that they were similar for most events."*

(f) Fig. 8 (P. 11408) has one red and two pink solid lines. The July 7 flight segment was chosen in the paper because it had two distinctive GW events in it. The south Florida and Caribbean region is typically rife with convective activities during that period of year. It is hard to find a case for which a GW could be traced to an isolated convective source and at the same time there were multiple GW events in the selected flight segment.

(g) Yes, *"vertical flux of horizontal momentum"* is implied here. We will use these words in the revised paper to avoid any confusion.

(h) In general, the waves we observe were above levels where ice clouds would form, but they came from below and must have passed through that region.

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Thus, the statistics on the waves should be relevant to ice cloud modelers who need statistical information about wave properties. We will mention the above in the revised paper.

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